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MAR 29 2005
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Patent
Attorney's Docket No. 015290-457

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	
Jerome S. Hubacek et al.	Group Art Unit: 1763
Application No.: 09/749,916	Examiner: LUZ L ALEJANDRO MULERO
Filed: December 29, 2000	Confirmation No.: 6834
For: ELECTRODE FOR PLASMA PROCESSES AND METHOD FOR MANUFACTURE AND USE THEREOF	

SECOND DECLARATION BY JEROME S. HUBACEK UNDER 37 C.F.R. § 1.132

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

I, Jerome S. Hubacek, hereby state as follows:

1. I am an inventor of subject matter claimed in the above-identified application.

2. Tests were performed under my supervision using low resistivity, single crystal silicon showerhead electrodes in a plasma reaction chamber. The showerhead electrodes had a plurality of gas passages (outlets) with diameters of 0.025 inch arranged to distribute a process gas in the reaction chamber during use of the electrodes. The showerhead electrodes had thicknesses of 0.15 inch, 0.18 inch, 0.25 inch, and 0.35 inch. The showerhead electrodes having thicknesses of 0.15 inch, 0.18 inch and 0.25 inch included 3249 gas passages, while the showerhead electrode having a thickness of 0.35 inch included 2437 gas passages. The showerhead electrodes had an electrical resistivity in the range of from about

0.005-0.02 ohm-cm. The showerhead electrodes were bonded to a graphite support member by an elastomeric joint.

Power levels of 1000 watts, 2000 watts, and 3000 watts were applied to each of the showerhead electrodes. In addition, a power level of 4000 watts was applied to the thicker showerhead electrodes having a thickness of 0.25 inch and 0.35 inch. The center-to-edge temperature gradients of the showerhead electrodes having a thickness of 0.15 inch, 0.18 inch, and 0.35 inch were modeled based on temperature measurements made for the showerhead electrode having a thickness of 0.25 inch. The test results are plotted in the graph in attached Appendix A. As shown in the graph, at each applied power level, the center-to-edge temperature gradient decreases as the showerhead electrode thickness increases. For example, at an applied power level of 2000 watts, decreasing the electrode thickness below 0.25 inch sharply increases the center-to-edge temperature gradient. At an applied power level of 3000 watts, increasing the electrode thickness from 0.25 inch to 0.30 inch reduces the center-to-edge temperature gradient by about 15% (on the centigrade scale). Increasing the electrode thickness from 0.25 inch to 0.35 inch at the same applied power level reduces the center-to-edge temperature gradient by about 35%.

3. The claimed showerhead electrode allows longer production times before replacement of the electrode is needed. Increasing the showerhead electrode thickness unexpectedly provides better thermal uniformity while increasing the lifetime of the electrode (i.e., the number of RF hours that the electrode can be used). Thicker electrodes allow an increase in the maximum amount of power that the showerhead electrode can be operated at without failure. At a set power level,

increasing the showerhead electrode thickness reduces the center-to-edge thermal gradient of the electrode (see Appendix A), which surprisingly reduces the probability of cracking of the electrode, especially at high power levels (e.g., 4000 watts).

4. The showerhead electrode thickness versus the power level applied to the electrode was measured, and the test results are plotted in the graph in attached Appendix B. The region above line A represents the experimentally determined operating range in which the probability of electrode cracking is low, while the region below line A represents the operating range in which the probability of electrode cracking is high. Extrapolation of line A to greater electrode thickness values shows that showerhead electrodes having a thickness of 0.25 inch or greater can be operated at significantly higher power levels than thinner electrodes.

5. Increasing the showerhead electrode thickness while using the same diameter gas passages in the electrode surprisingly reduces particle contamination of processed wafers. The increased length of the gas passages also increases the gas pressure behind the electrode. Showerhead electrodes having a thickness of 0.25 inch and larger reduce deposition of polymer particles behind the electrode, as compared to the electrodes having a thickness of 0.15 inch and 0.18 inch. The claimed electrode can provide beneficial reduction in particle defects.

6. The claimed showerhead electrode provides better RF coupling than thinner showerhead electrodes. As increasing the thickness of the showerhead electrode decreases the electrical resistance of the electrode from the center to the

edge, ohmic losses in the electrode can be reduced. Coupling of radio frequency (RF) power to plasma generated in the plasma reactor can be enhanced. As shown in the Table at page 14 of the above-identified application, reducing the impedance path of the RF results in a higher etch rate of substrates in the plasma reactor using the same gas chemistry and reactor conditions, including the same set power level applied to the electrode.

7. Reducing the electrode resistance also improves plasma confinement in the plasma reactor. Tests were performed under my supervision using four, low resistivity, single crystal silicon showerhead electrodes A-D and also a standard higher resistivity single crystal silicon showerhead electrode in a plasma reaction chamber. The low resistivity showerhead electrodes had a thickness of 0.25 inch and an electrical resistivity of from about 0.005-0.02 ohm-cm. Low resistivity showerhead electrode A included 829 gas passages with diameters of 0.025 inch, and low resistivity showerhead electrodes B-D each included 3249 gas passages with diameters of 0.025 inch. The standard resistivity showerhead electrode had a thickness of 0.25 inch, an electrical resistivity of 10 ohm-cm and included 3249 gas passages with diameters of 0.025 inch. The showerhead electrodes were each bonded to a graphite support member by an elastomeric joint.

The standard resistivity and low resistivity showerhead electrodes were installed in a plasma reactor including plasma confinement rings for confining the plasma in confinement region between the showerhead electrode and the lower electrode. A process gas (i.e., a gas mixture of $Ar/CF_4/O_2/CHF_3$) was energized to produce plasma in the plasma reactor by applying 1000 watts power at a frequency

of 27 MHz and 2000 watts at a frequency of 2 MHz to the lower electrode while the upper electrode was grounded (i.e., provided a return path). Each of the electrodes was tested to determine the maximum flow rate of a constituent of the gas mixture (argon) that could be used without plasma unconfinement in the plasma reactor, i.e. the gas flow rate above which the plasma was no longer confined within the plasma confinement rings.

The flow rate of argon was increased while maintaining the same flow rates of the other gases of the gas mixture. The test results are shown in Appendix C. As shown, for the standard resistivity showerhead electrode, there was plasma unconfinement at an argon flow rate of less than 200 sccm. In contrast, for the low resistivity showerhead electrodes, higher argon flow rates ranging from 200 sccm (showerhead electrode D) up to 1000 sccm (showerhead electrode A) were used with stable plasma operation. The higher argon flow rates provide a larger confinement window for plasma processing operations using the low resistivity showerhead electrodes.

Appendix D shows the measured impedance values for the low resistivity showerhead electrodes A, B and D, where power at frequencies of 2 MHz and 27 MHz was applied separately to the lower electrode. As shown in Appendix D, for both operating frequencies, showerhead electrode A had the lowest impedance value, showerhead electrode D had the highest impedance value and showerhead electrode B had an impedance value between that of electrodes A and D. Accordingly, the impedance values shown in Appendix D correlate to the plasma confinement results shown in Appendix C for the low resistivity showerhead electrodes. That is, decreasing the impedance of the electrode improves

confinement. Such performance benefits are highly desirable in semiconductor processing because by improving confinement, the confinement window and the corresponding process window are increased.

8. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: 3/25/05

Jerome S. Hubacek

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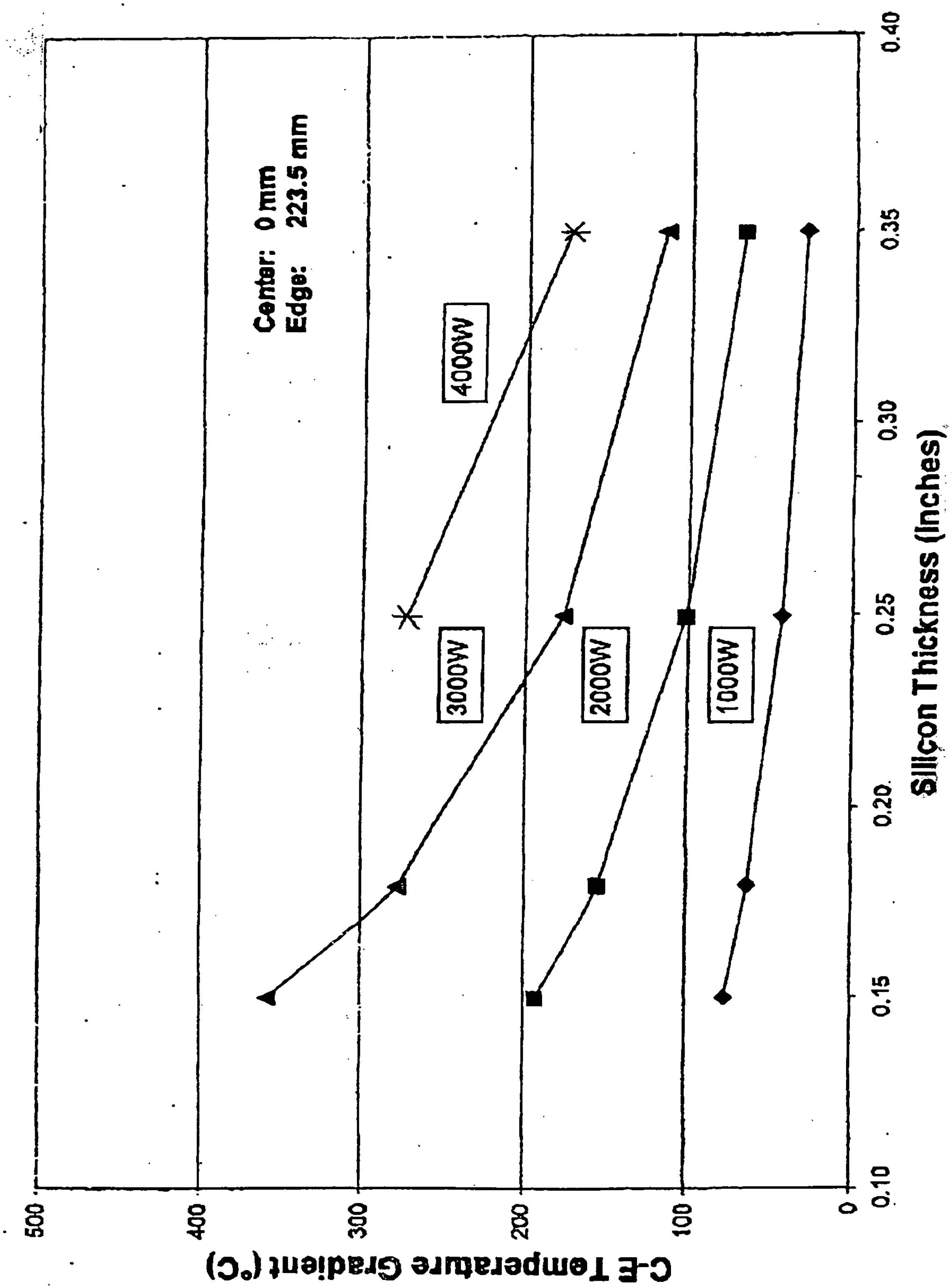
Appendix A



Appendix B

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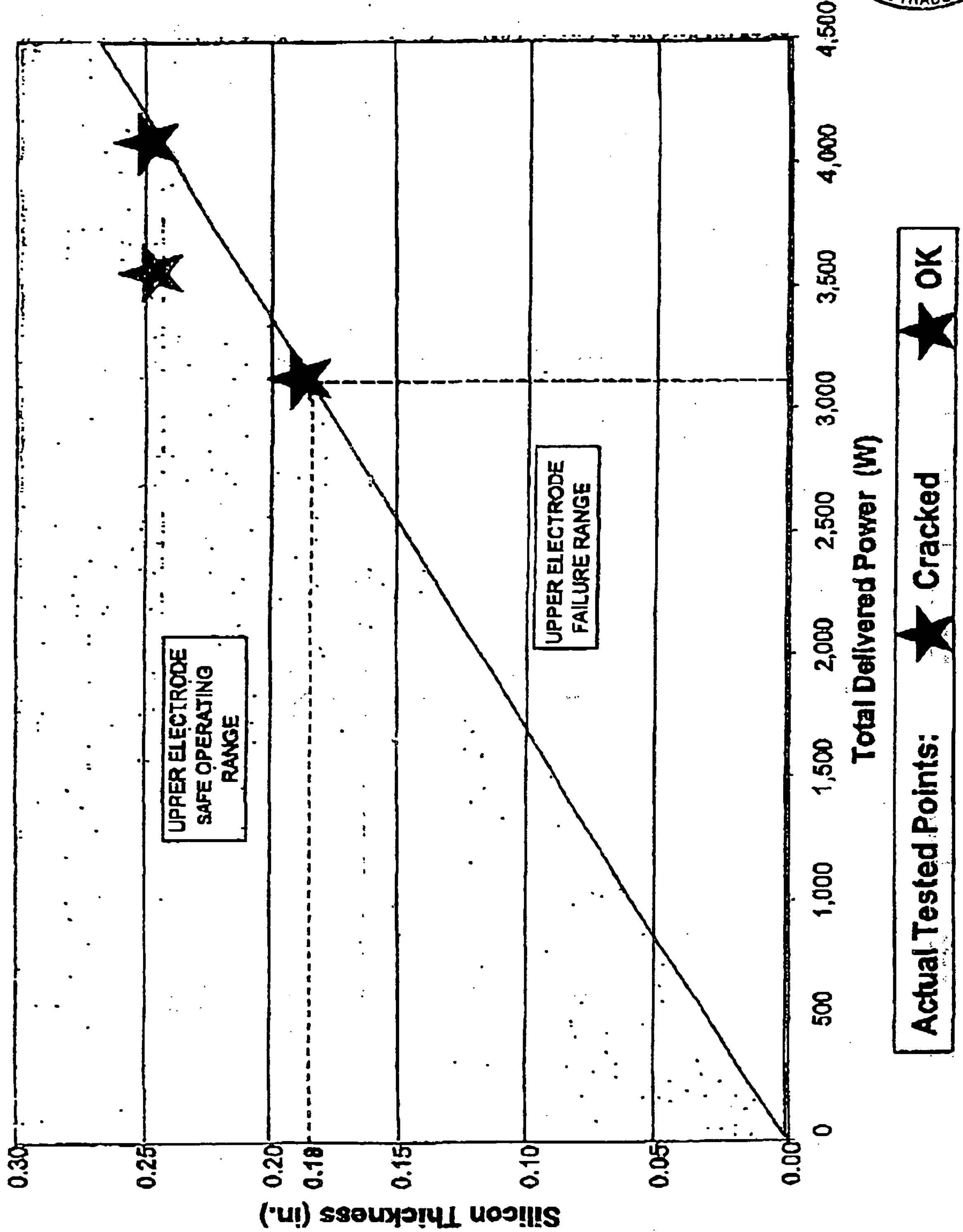
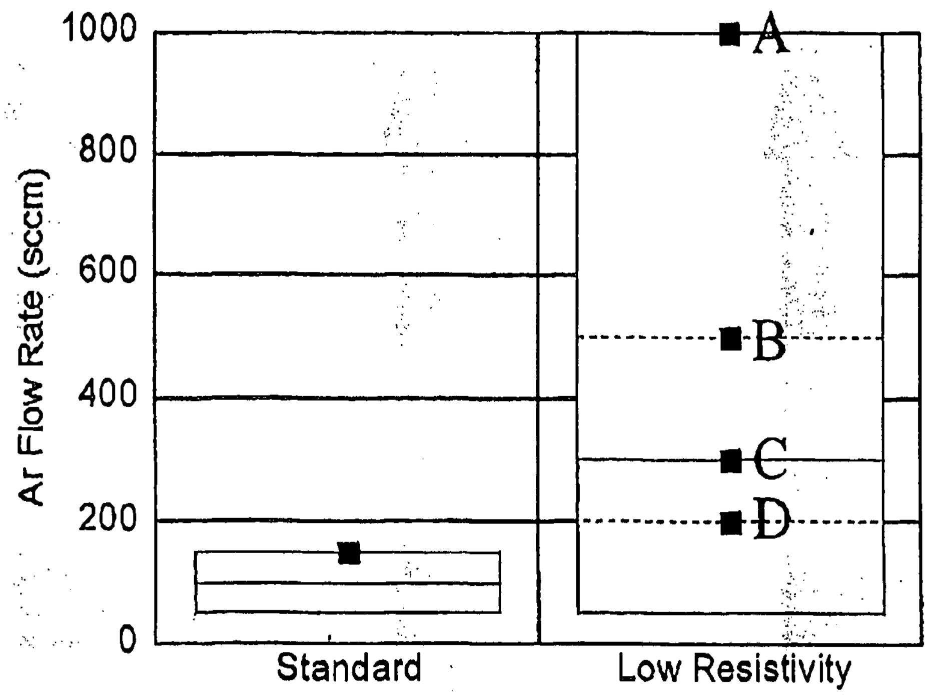
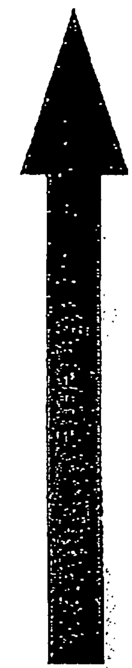


Range of Ar Flow Rates for Stable Plasma Operation





A: P/N 716-461378-JH2 S/N 16625-6	829 hole low resistivity electrode
B: P/N 839-011907-121 S/N 1047-9	3249 hole low resistivity electrode
C: P/N 839-011907-121 S/N 1047-15	3249 hole low resistivity electrode
D: P/N 839-011907-121 S/N 1047-21	3249 hole low resistivity electrode

Appendix C

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Appendix D

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